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# Integration of Measurements and Maneuvering Technologies Used to Modify Caisson

No. 2A-2

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## ABSTRACT

The modification of the caisson drydock is in many ways more difficult than conventional ship modifications. This is because of the accuracy required, location of the measurements and the size of the structure. The development of computer based multi-headed electronic theodolite systems made it possible to extract accurate data on large structures. This data was formatted so it could be input directly into a computer aided design system. The multi-headed electronic theodolite system was used to transfer new design information directly to the structure. The caisson structure was modified and moved safely into position with the aid of a water castor system for final assembly. Final dimension checks verified the accuracy of the system.

## BACKGROUND

Philadelphia Naval Shipyard's Drydock No. 3 is one of the deepest graving docks on the East coast. Built in the 1920's, its original planned mission was to provide a full service drydock for all ships of the United States Navy, including battleships. The original caisson for this drydock was still in use in 1990. It was a hydrometer style caisson of riveted construction. The caisson acts as a dam to seal the drydock opening and needs water ballast to maintain its position and provide an effective seal. Any significant reduction in ballast due to loss of water could result in catastrophic flooding of the drydock. The caisson had major corrosion of structural members in the trim and ballast tanks. Its top deck or walkway was wooden and in need of replacement and the rivet seams were in poor condition and weeping. Because of the poor condition of the caisson, major repairs were budgeted so the drydock could continue in a certified status.

Repairing this old riveted structure in the 1990's posed major

problems. Major structural elements on the inside would have to be replaced. There would have to be a great deal of welding close to rivets. Major structural members embedded in concrete appeared to be corroded. Most importantly, all of the rivets on the structure had been ring welded and seams were leaking, so there was no way to properly sound rivets and certify the structural integrity of the overall structure.

A new caisson was estimated to cost over 4 million dollars, which exceeded the repair budget. Fortunately there was a large caisson on the base which was built by the now defunct, New York Shipbuilding Corporation (NYSC) Figure (1). It had been in service in Camden, New Jersey, for a special drydock used in the construction of the USS KITTY HAWK (CV63) in the mid 1950's. Because the caisson was stored in fresh water and had only limited use at NYSC, it was in virtually new condition. The overall dimensions of the caisson, with the exception of the length (8.38 m, 27.5 ft longer) were very similar to the original caisson. Its all welded construction made it easy to modify.

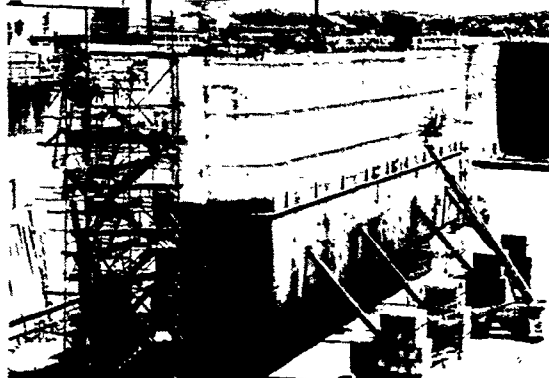


Figure 1.  
New York Shipbuilding Corp. Caisson

As a final feasibility check, the dimensional attributes of both the drydock seat and the NYSC caisson were measured using conventional tools such as steel tapes and plumb bobs. The survey was accurate enough to verify

that the NYSC caisson could be made compatible with the drydock opening. However, it failed to show discrepancies based on existing plans in the slopes between the caisson and the drydock and the radii at the corners. In addition, the overall length of the drydock opening appeared to be in error. It was therefore determined that a more accurate means of measurement would have to be used if accurate design modification details were to be developed.

#### INITIAL SURVEY

The measurement tool of choice for this project was multi-headed electronic theodolite system (AIMS II; Analytical Industrial Measuring System). This system consist of two (2) theodolites linked electronically to a personal computer to give real time data. The theodolite system was the logical choice due to several factors. Data points of the drydock opening (seat), although visible only from the river side could be captured from the drydock floor. Secondly, the new caisson would be located in the center of the same drydock. The stability of the drydock floor allowed the measurement group to use the theodolite system and not be restricted to other measurement tools, such as photogrammetry. Finally, time constraints required a quick turnaround of accurate data.

The first task for the measurement group was to provide data of the existing drydock opening (figure 2). Determination of theodolite positioning was the first concern. Placing the instruments between the inner and outer seat was eliminated for two reasons. First, a limited sight distance and very poor geometry between the theodolites and the data points impeded the accuracy. Second, with the existing caisson continuously leaking and the readings taken in the winter months, very hazardous safety conditions existed in this area with partial freezing of standing water. It was then determined that the theodolites would have to be located on the drydock floor. This created a situation where most of the data points would be hidden from sight (figure 2).

Hidden points were captured using a hidden point stick which is a targeted measured rod. By sighting the targets of the rod the theodolite system can automatically interpolate for the hidden point using the software (hidden point routine) provided with the system. Data for the drydock seat area were taken at various stations with two points per station. One representing the upper edge of the seat, which was visible and the other representing the bottom corner which was hidden. Points were taken at four stations along each side. Also,

points were taken at 15 stations in the radius area, because it was critical for fit.

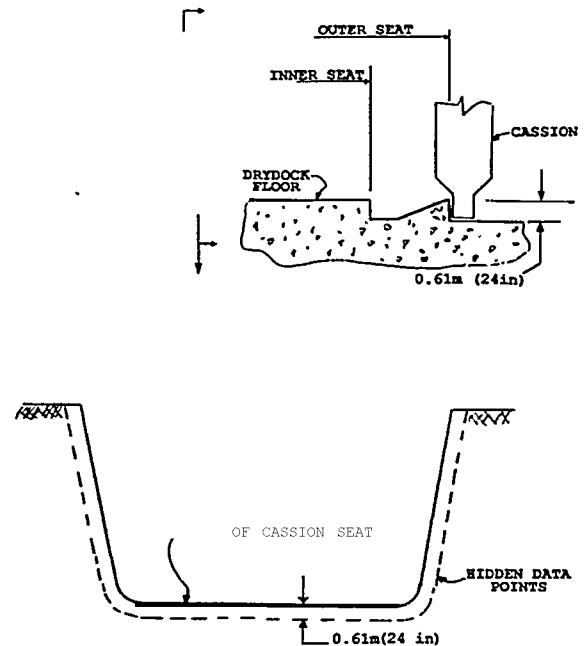


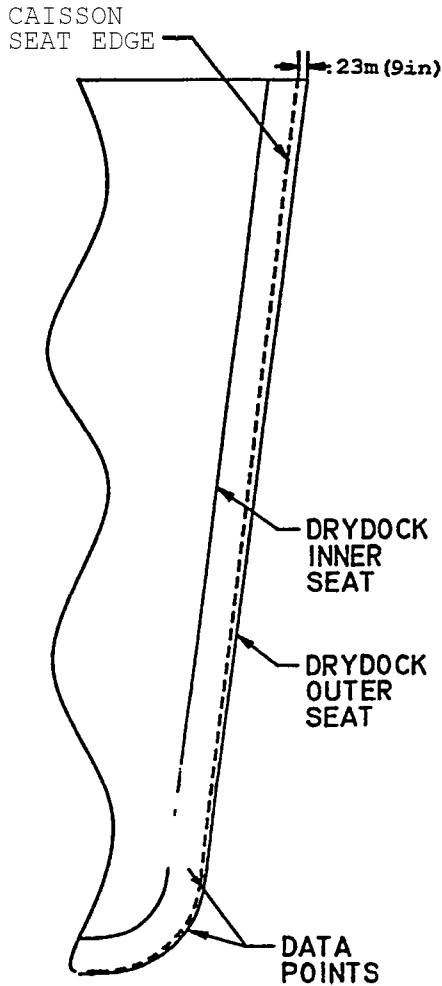
Figure 2.  
Drydock NO.3 Opening

The second part of this initial measurement phase was to establish the outline dimensions of the new caisson. With the new caisson on blocks in drydock 3 the theodolites were located on the drydock floor. From this vantage point, the dimensions required were captured. Data points were taken along the sloping ends at four locations. The radius corners were identified by data points at each tangent point and three intermediate points. Other key dimensional locations were captured such as the top deck of the knuckle areas and the bottom seat area. Each point was located first by sighting with a laser attached to the theodolite. These points were then scribed in for reference for future modification and dimensional checks.

The measurement data from this initial phase was electronically transferred to the structural department's CAD (Computer Aided Design) system. This would lay the ground work for the entire project and allow the structural department to work from accurate data when determining the structural modifications required for not only correct fit of the new caisson to the drydock opening, but also to ensure proper buoyancy and structural integrity.

## CAD DEVELOPMENT

Data taken from the survey was transferred (using a 5 1/4" floppy disc) directly into the shipyard CAD system. This allowed viewing all the data taken in three dimensions. By using curve fitting techniques, an accurate picture of the seat of the caisson and the drydock opening could be obtained. Figure 3 shows a CAD overlay of some measurement data taken.



**FIGURE 3.**  
CAD OVERLAY OF THEODOLITE DATA

The slope, radius and depth of the seat would all be critical dimensions which interplay with one another. It was decided early in the design process that the modified caisson should have approximately .076 meters (3 inches) clearance on each side of the sloping drydock side walls. This clearance would provide for dimensional changes in the structure and allow sufficient operational clearance to seat the

caisson in a muddy river environment where debris can easily be lodged between the caisson and the drydock wall. While the task may seem easily solved by a conventional layout process, it becomes much more difficult when one considers that the design must allow for a good seal if all clearance is shifted to one side. Also, mud in the seat under the bottom of the caisson could cause it to tilt forward from the side walls. A CAD simulation would allow for these or any combination of other conditions to be examined with the caisson modified in many different ways.

The measurement data verified our initial dimensional analysis of the caisson proving that the drydock seat and the seal area of the NYSC caisson had different slopes. Additional structure would have to be added to the sides of the caisson which had less slope. This would prevent an excessive clearance at the top of the seal area.

The radii between the ends of the caisson and drydock wall were sufficiently different to allow for clearance but the position of the centers between the two would be critical in determining fit clearance. If positioned too close, the curved surfaces would intersect which would cause the caisson to rest on its curved edge rather than rest along its base. If too much clearance was allowed it would be impossible to maintain a good seal along the sloped sides.

Several different scenarios were evaluated. The most cost effective one was to modify the caisson asymmetrically by adding structure to one side only. This would make the clearance different at the ends if the caisson were positioned at the centerline of the drydock. But the clearance would still be within allowable tolerances if the caisson were shifted to one side or rotated 180 degrees. By jogging the seal about 6.1 meters (20 feet) from the base and removing 8.38 m (27.5 ft) from the center of the caisson we were able to meet all dimensional clearance criteria. Final dimensions are shown in Figure 4.

## LAYOUT

The second task for the measurement group involved translating the dimensional data. For removing the center section, from CAD to the caisson itself. Design engineers had determined the optimum location for the center section removal which would ensure the structural integrity of the two remaining ends once rejoined. To establish these dimensions the existing caisson, physical measurements from internal structural members were made. These data points were then established by drilling a hole through to the outside of the caisson. This

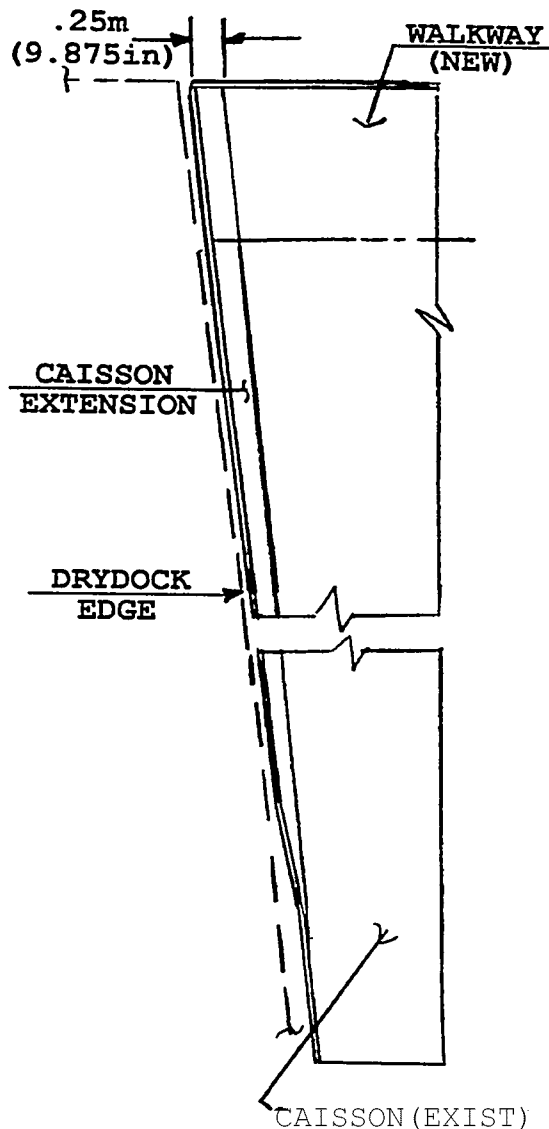


Figure 4.  
Caisson Final Dimensions

hole was sighted by the theodolites and used as a reference point for inside and outside dimensions. Laying out of two parallel lines is relatively easy until one realizes that these lines must pass under the caisson up the backside, along the top and eventually end up at the same starting point while remaining paralleled throughout. Several setups and transitions from pass point to pass point were required. The accuracy of the system and the attention to detail of the system operators proved to be the cornerstone to the success of this project.

#### MODIFICATION AND ASSEMBLY

Production shops used the cut lines layed out by the measurement team to precisely cut a perfect match

between the two halves of the caisson. Shipfitters and welders worked to remove the large portions of plating and beams from the center section (Figure 5).

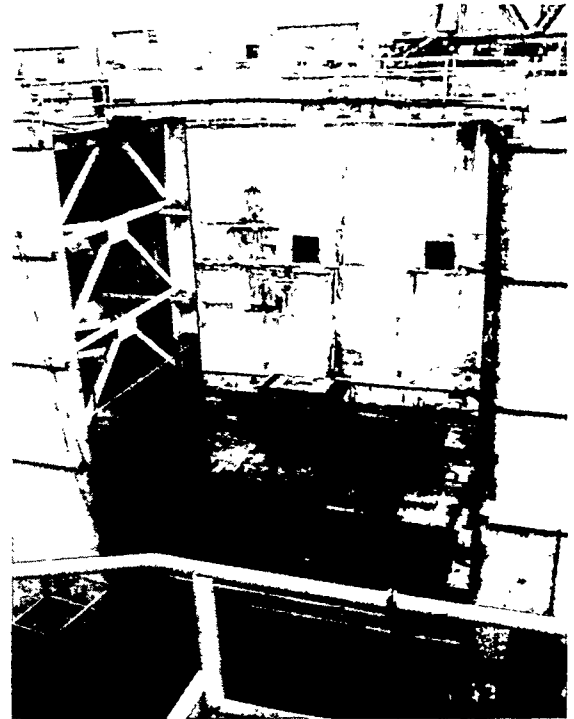


Figure 5.  
Steel Removal, Center Section

The area of steel removed was about 8.38 m (27.5 feet) long, 10.67 m (35 feet) high and 6.1 m (20 feet) wide across the top.

The bottom portion of the caisson contained a large amount of concrete used mainly for ballast. A concrete cutting company was tasked to make one cut at each end of the center section so that shipyard riggers could "roll" the loose wedge of concrete out of the way (Figure 6 and 7). The wedge removed was about 8.38 m (27.5 feet) long by 6.1 m (20 feet) wide by 3.35 m (11 feet) high and it weighted about 250,000 KG (275 short tons). The cutting of the concrete was accomplished using a diamond strand blade which runs through a main drive assembly around the concrete to be cut and back through the assembly. Each cut took about 10 hours.

The shipfitters then installed temporary supports to the concrete section's steel skin (Figure 8). The supports were designed by shipyard engineers and a drawing was prepared to provide direction to the shops for fabrication of the supports. In addition, steel plates were laid on the floor of the drydock to provide a path for the concrete section to travel. A steel plate guide was placed on the inside of the path to keep the section from drifting. Riggers then used the

273,000 KG (300 ton) jacks to raise the



Figure 6.  
Concrete Cutting; Top View

section about 0.1 m. (4 inches) to insert 4 mini-rollers under the temporary supports. The main problem with the mini-rollers was shifting of the rollers under the supports which caused delays in the move. The rollers had to be realigned under the center of the load from time to time to avoid any instability. Unevenness in the drydock floor, regardless of the presence of the steel plate path was the main reason for the mini-rollers shifting.

Keel blocks were stacked about 12.2 m (40 feet) from the concrete wedge at the end of the steel path described above.

Chain falls were connected between the keel blocks and the temporary supports to allow riggers to pull the section from between the two halves of the caisson (Figure 9). This process took about six hours.

The movement of the two halves of the caisson was accomplished by using water castors to "float" one half to the other along a steel plate path. The process was very safe, provided maximum control, required very little horizontal force to move the section, and was cost effective. Two other options were considered, floating the sections in place and using a rail system. The idea of floating one half of the caisson to the other is the typical one of choice used by shipyards in shortening or enlarging ship midsections. For example, this was the method used in the down sizing of the

KEYSTONE CANYON in 1990 by Northwest Marine. As noted in reference (1), the bow section had to be refloated three times before alignment was



Figure 7.  
Concrete Cutting; Side View

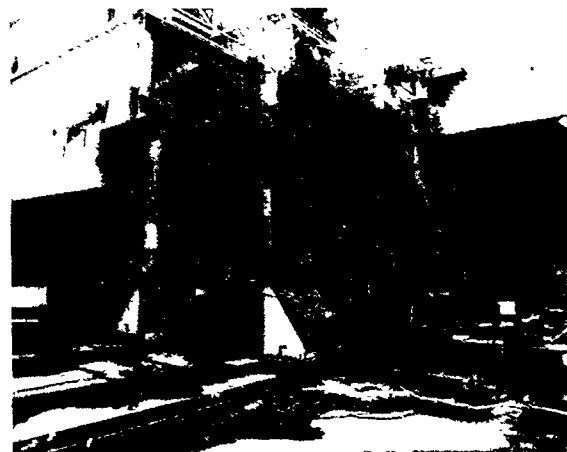


Figure 8.  
Temporary Supports For Concrete Removal

adequate to begin welding. This method was quickly eliminated due to the cost of flooding the drydock and the need to build a coffer dam at the open end of the section. In addition, the lack of total control of the buoyant section for repositioning made this method unacceptable. Another option considered was a rail system but it proved to be too expensive due to the high cost of building a very large structural system to accommodate multiple rollers.

The castors operate on a water film created under the castor by water leaking from the bottom of a diaphragm (Figure 10).

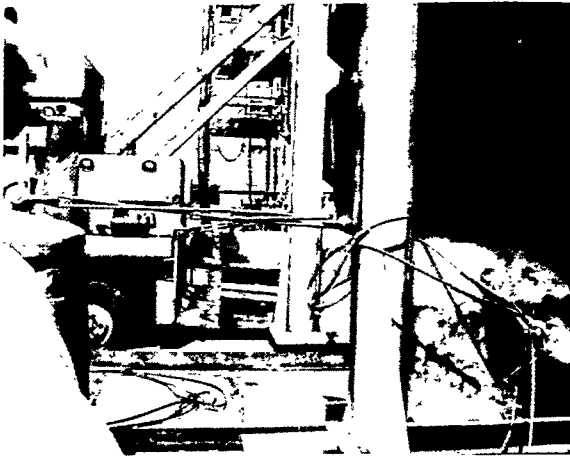


Figure 9.  
Rigging For Concrete Removal

This allows the entire castor/caisson to "float" just like a glass filled with fluid on a wet smooth surface. The castors are flexible, so they could accommodate the lack of flatness of the

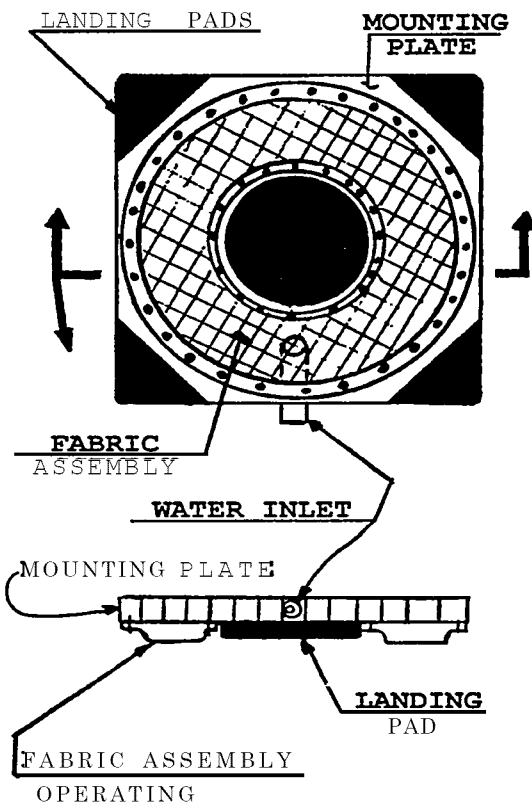


Figure 10.  
Water Film Castor

drydock floor. Also, because of their flexibility the load per castor would remain fairly constant during the move, allowing the supporting steel fixture to be optimised around well defined factors of safety. Steel plates welded together were placed along the drydock floor to prevent loss of water due to small irregularities such as holes in the concrete surface. The castors moved with the caisson along the steel plate track due to the differences in friction between the temporary support surface and the steel path surface. The castors used during the move required about  $0.483\text{N/mm}^2$  (70 PSI) of water pressure at each of the castors in order to obtain 0.08 m (3 inches) of lift off the keel blocks. Production shops manufactured two separate manifolds with ten gauges, each dedicated to one castor for monitoring purposes.

The castors were rented with a representative from the vendor providing technical characteristics such as load capacity, friction factors, surface slope, and water supply. Using this information, temporary supports made of steel I beams and plates were designed. Each support was fabricated out of three I beams spaced like a tripod, over each castor to handle any rotations (Figure 11).

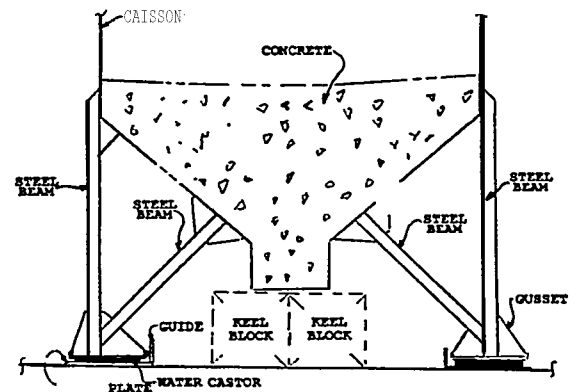


Figure 11.  
Temporary Supports For Floating Half of Caisson

In this way the lifting force at the center of pressure of the castor, would remain stable in the area defined by the supporting legs. Calculations showed that a total of 20 castors would be required providing a capacity of 725,750 kilograms (1.6 million pounds). The section to be moved was 589,670 kilograms (1.3 million pounds) and the center of gravity was calculated to be 3.05 m (10 feet) up from the bottom. The castor model chosen was by AERO-GO and its designation was 4K48HDL. It was 1.22 m (4 feet) by 1.22 m (4 feet) by 0.07 m (2.75 inches) thick with a lift of 0.08 m (3.0 inches). The castors were placed between the temporary

supports and a relatively "flat" steel path similar to one provided for the concrete removal.

A guide track was installed along the path, laid on both sides of the caisson, to keep the caisson from "floating" off the steel path. In addition, guide wires were placed from the top of the caisson to tiedown fixtures at the top of the drydock to provide additional control. The floating section of the caisson was pulled to the stationary section by using chain falls. The final position of the two halves are shown in figure 12.



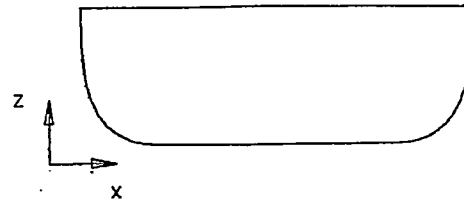
Figure 12.  
Final Position of Caisson Halves

Two ten ton chain falls proved more than adequate as the floating section moved easily. A maximum of 0.15 m/min (.5 ft/min) movement between the stationary and floating section was maintained to avoid the moving section from developing excessively high momentum. Shipfitters quickly welded steel flat bars perpendicular to the two caisson accross the unwelded seam to prevent relative misalignment of the two halves.

The third and final task for the measurement group was to make a final check prior to production welding. The bringing together of the caisson was complete by the end of the first shift on a Tuesday. With the start of the second shift, the measurement group set up the theodolite system and began the final check of key control points along the entire caisson. With the data points measured in three dimensional coordinate system, it was possible for the measurement group to verify the final construction configuration during the same second shift. Table I shows a comparison of design dimensions and final measured dimensions. The go ahead for final production welding was given the following morning (1st shift Wednesday).

POINT I

POINT 2



	POINT I		POINT 2	
	DESIGN	MEASURED	DESIGN	MEASURED
X	0.0	0.0	39.61M (1559.501N)	39.63M (1560.107N)
Y	0.0	0.0	0.0	0.005M (0.19271N)
Z	15.11M (595.001N)	15.13M (595.611N)	15.11M (595.001N)	15.12M (595.24621N)

TABLE 1. DESIGN DIMENSIONS VS. MEASURED DIMENSIONS

There was no need for additional fitting, and welding the large seam connecting the two halves could begin, as well as welding many internal stiffeners. Shipfitters also proceeded to install an additional steel section to one end of the caisson so that the rubber seal would rest on the drydock seat when the caisson was finally installed. In addition, they also added a steel walkway about 1.21m (4 feet) on top of the caisson to raise the height of the caisson to that of the existing drydock opening.

Internal modifications and repairs to electrical and mechanical systems of the caisson were also made. Paint and preservation measures were made inside and out, making the completed caisson ready for operation.

#### CONCLUSION

This project proves that a multi-headed electronic theodolite system in a drydock environment can extract data and layout data accurately to achieve a first time quality fit for large structures.

In addition, the use of the theodolite system and CAD system allowed for the rapid and accurate transfer of large amounts of data.

These systems made it possible to implement a well coordinated plan of attack throughout the project's duration. Communication between design, measurement and production groups was an essential ingredient to the success of this project.

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